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# Monitoring Human Health and Performance using Body-worn Motion Sensors*

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**Jeffrey Somers, NASA Johnson Space Center, Houston, TX**

*This work was funded by NASA Exploration Capabilities.

Presenter

# KJ Kim, PhD

*Human Performance Data Engineer*

H-3PO Lab | HHPC | KBR

## BACKGROUND

- Joined the Human Physiology, Performance, Protection & Operations (H-3PO) Laboratory in 2019.
- Perform research and provide operational expertise in several technical areas:
  - Exercise Physiology & Countermeasures (EPC)
  - Space Suits & Exploration Operations (SSEO)
  - Applied Injury Biomechanics (AIB)
- The biggest challenge in my career has been transitioning from a ‘Signal Processing Engineer’ to a ‘Rehabilitation Engineer’ to a ‘Human Performance Engineer.’
- Publications of 24 refereed journal articles, 40 conference proceedings & abstracts, 15 registered patents (USA, Europe, Japan, and South Korea).
- **KBR’s Tech Fellow** in Human Health & Performance – Signal Processing
- **NASA JSC Director’s Innovation Award** for the development of multiple innovation processes that increase efficiency and improve accuracy in analyzing biomechanics and physiological data.

## EDUCATION & TRAINING

- BS/MS/PhD: Electrical Engineering, Hanyang University, South Korea
- Postdoctoral at the University of Miami Physical Therapy

## FUN FACT

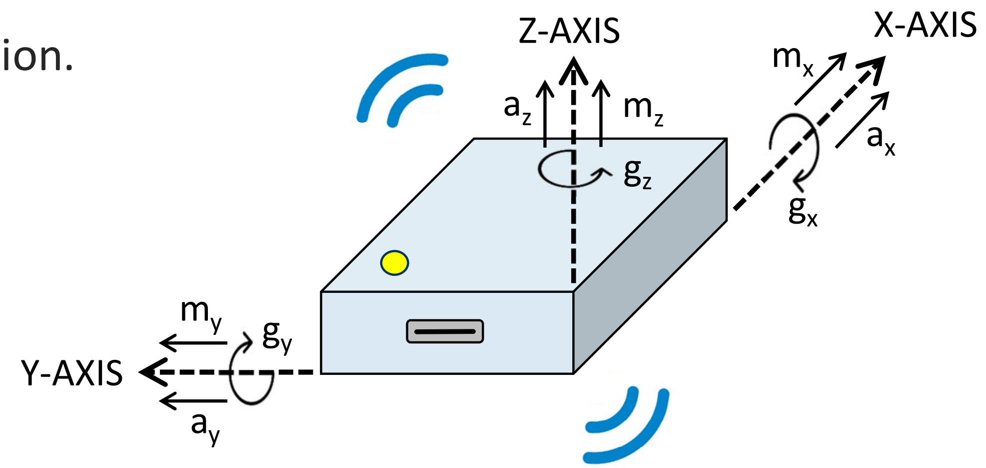
- I love chicken wings, but those always make my stomach uncomfortable.

NBL testing

Egress testing

# What Will Be Covered

- What is an inertial measurement unit (IMU)?
- Why do we need to monitor human motion via IMUs?
- Applications for the astronaut population.



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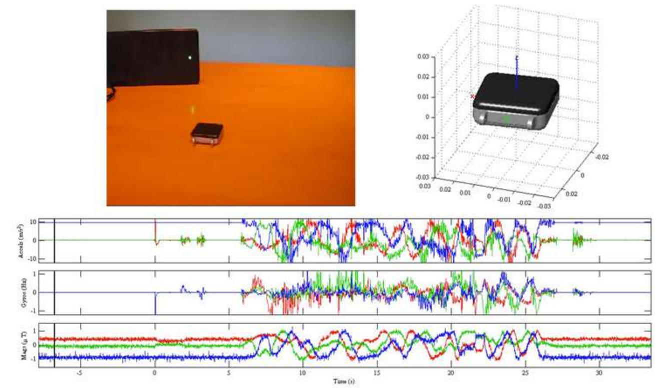
# Body-Worn Sensor for Motion Tracking

- ***Inertial Measurement Unit (IMU)***
  - A wearable motion sensor measures multi-axis
    - accelerations (accelerometer),
    - angular rates (gyroscope), and
    - direction of magnetic north (magnetometer).
  - Wireless, body-worn, small, portable, and not constrained by time and place.
  - Weaknesses:
    - Displacement error due to integration
    - Magnetic field distortion



APDM

XSENS



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# Wearables for Monitoring Human Health and Performance

| | |
|---|---|
| Frequent assessments | Objective evaluation |
| Continuous monitoring | Increased sensitivity |
| Daily activity measures | Reduced cost burden (No gait lab needed) |

Addressing the pressing issues that affect human health and performance while incorporating new technology

# A Big Change in the Spacesuit

- NASA's spacesuits are making a big change.

Lunar geology during Apollo 15 EVA
(Photo credit: NASA)

Mark III spacesuit during ARGOS testing

Next-generation spacesuit for the Artemis mission
(Image credit: NASA)


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# Gait Analysis (1/3): Planetary EVA Testing

**Walking will be one of the common exploration tasks on the Moon during the Artemis program.**

- ***Why is Gait Analysis Important?***
  - To help NASA scientists and engineers evaluate gait dynamics and performance in unsuited and suited conditions.
  - To demonstrate unique characteristics and limitations of EVA training facilities.

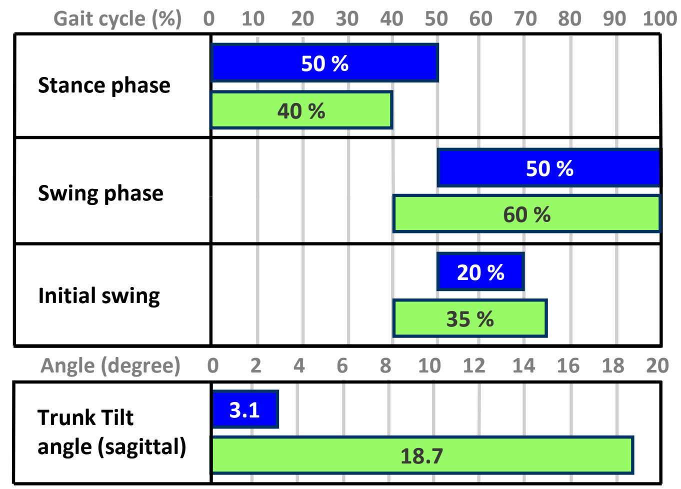
**[Unsuited] Lower-limb kinematics during walking**

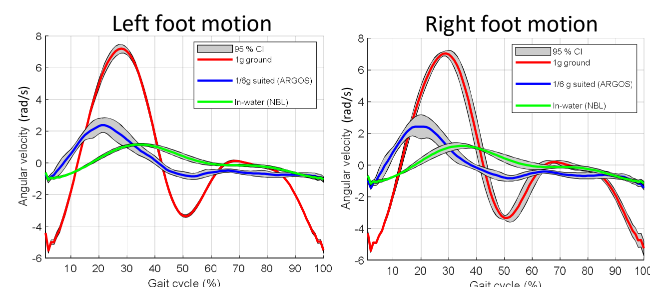
***1g Ground*** ***1/6g NBL***


**[Suited]**

***1/6g ARGOS***

***1/6g NBL***

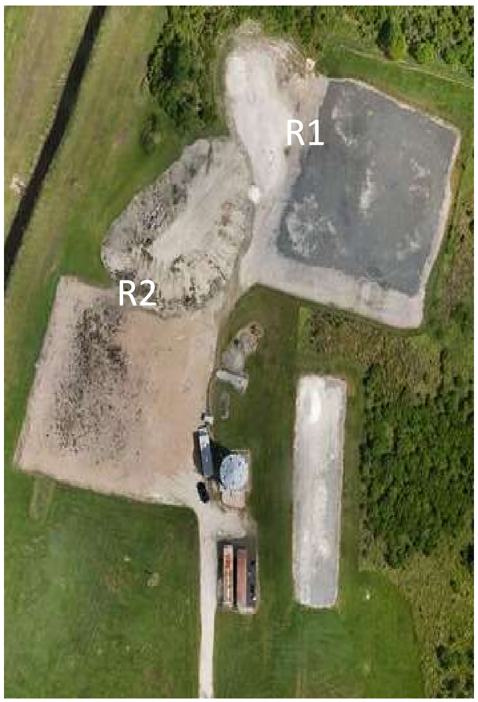


# Gait Analysis (2/3): Analog Testing

**The strategies to adapt to walking environments affect gait dynamics and the related metabolic cost.**

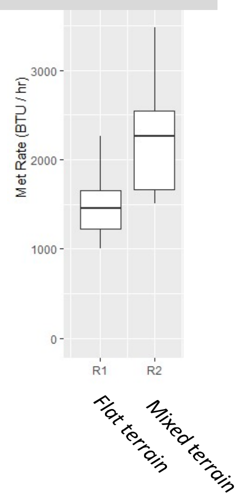
Planetary analog test site (rock yard) at NASA JSC



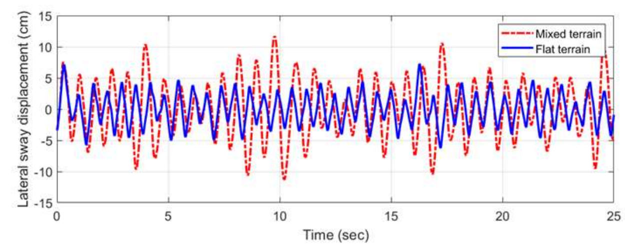

[Complex terrain ]

- Locomotion on the moon could be challenged by terrain conditions. How much energy is consumed to adapt to Lunar terrain?

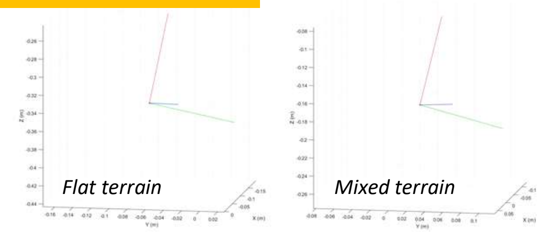
Metabolic rate




Upper body sway




Foot movement trajectory



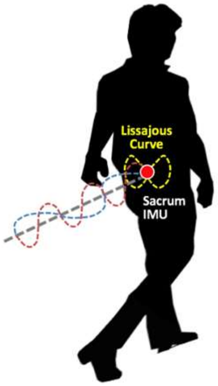

*Gait regularity: 91%* *Gait regularity: 48%*

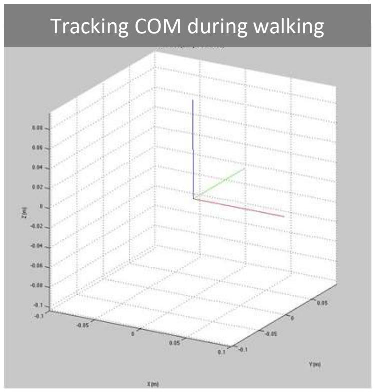
# Gait Analysis (3/3): Analog Testing

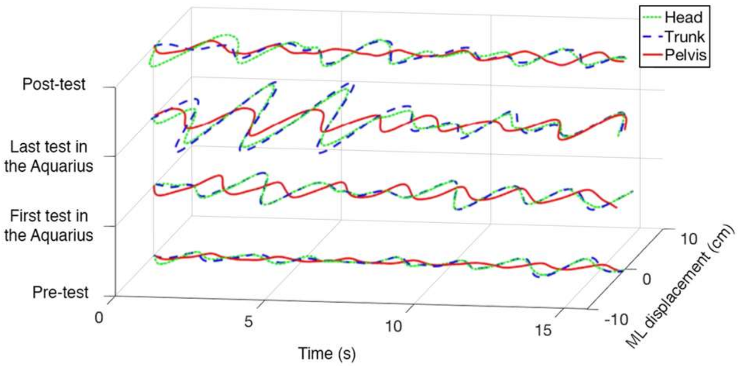
**NEEMO (NASA Extreme Environment Mission Operations)**

- ***Aim***
  - To investigate changes in sensorimotor performance due to exposure to the extreme mission environment.
- ***Method***
  - Instrumented crewmembers using body-worn IMUs
  - Measured performance of tandem gait (dynamic balance)

Tandem Walk



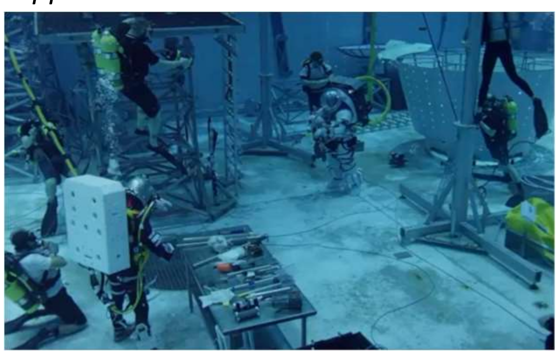

Kim, et al. (2018) Exposure to an extreme environment comes at a sensorimotor cost. *Nature - npj Microgravity.*

# Posture Assessment

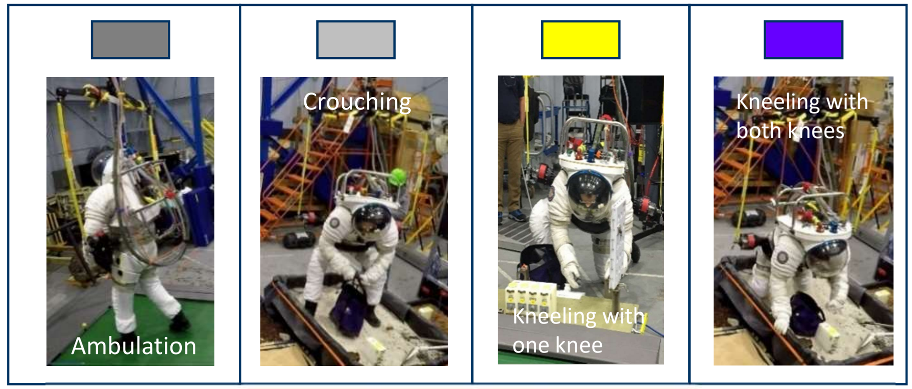
- ***Automated Activity & Posture Classification***

*Next Generation Exploration Spacesuit*

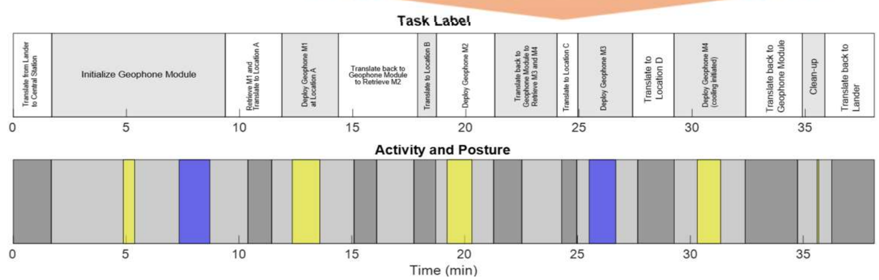
**Applied to the ARTEMIS Test Series at NBL*

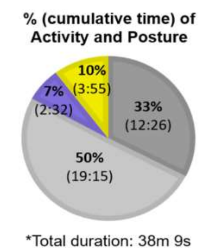


*Various activities and postures during ARGOS testing*




**IMU + Machine Learning**




** We are currently characterizing activities and postures to have quantitative data for work-domain and engineering evaluation of the next generation spacesuits.*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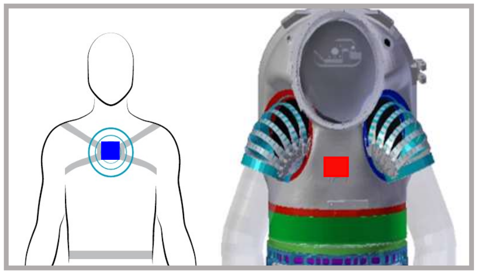
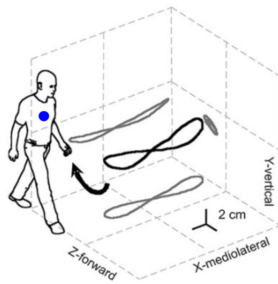
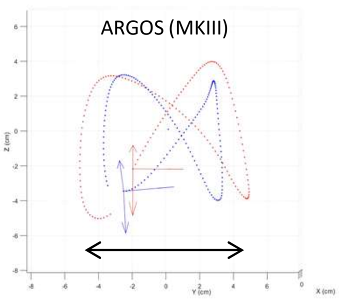
# Inside-Outside Motion Analysis

- IMU location on the upper body



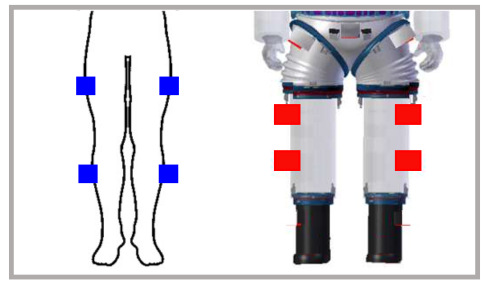



- Movement trajectory from **inside** and **outside** IMUs during walking

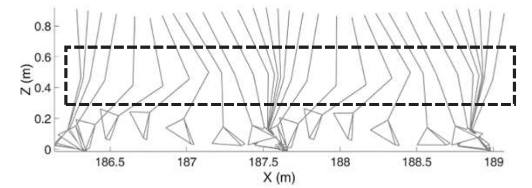



- Findings & lesson learned
  - The trunk IMU measured the upper body sway during walking, a butterfly-like pattern.
  - The inside upper body drives the outside suit.

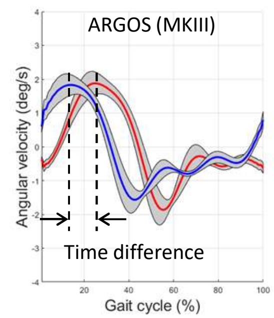
- IMU location on the lower limbs



- Knee angular velocity calculated from thigh/shank IMUs




- Gait pattern from **inside** and **outside** IMUs




- Findings & lesson learned
  - Two IMUs on the thigh and shank enabled to monitor knee joint angular velocity.
  - The inside upper body drives the outside suit.
  - The IMU system is the one and only device to perform inside-outside motion analysis.